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ABSTRACT

This experiment examined the relationship between computer programming and the following factors: mathematical ability, locus of control, introversion/extraversion, anxiety, and task time allocation. The programming performance of 14 male and 18 female students in a college-level introductory computer science course was measured by means of a math pretest, which was employed as a cognitive measure; three different personality trait questionnaires measuring introversion/extraversion, anxiety, and locus of control; and a 50-minute practical programming examination. Unexpectedly, math ability was not found to be a significant predictor of programming ability; however, time allocation to interactive program implementation was positively correlated with programming performance, suggesting that internals would be more likely to succeed at program implementation than externals. Findings also advise caution in utilizing mathematical pretests as the sole predictors of computer science success, and suggest that tests for personality traits such as internality may prove to be useful additions to tests that advise students of their chances of computer science success. A list of 14 references and four data tables complete the report. (JB)

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Personality and Cognitive Factors Influencing Computer Programming Performance

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Running Head: Factors Influencing Computer Programming

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Abstract

The present experiment examined the relationships between computer programming and the following factors: mathematical ability, locus of control, introversion/extraversion, anxiety and task time allocation. Math ability was not foound to be a significant predictor. Time allocation to interactive program implementation was positively correlated with programming performance. Among the personality traits, internality correlated with programming performance accounting for 14 percent of the variance. These results suggest caution in the sole use of mathematical pretests as predictors of computer science success. In addition, locus of control may be an important personality trait to consideras a factor related to computer programming ability.

Personality and Cognitive Factors Influencing Computer Programming Performance

Previous research concerning factors influencing computer programming, while providing valuable data, has failed to directly measure the simultaneous effects of cognitive and personality variables on performance. The present study, in an attempt to determine the role of these variables, specifically examines mathematical ability, time allocation, locus of control, extraversion/introversion, and anxiety as possible factors affecting computer programming performance. These variables were selected since a review of previous work in this area indicated that while each of these variables had been examined previously, results were often inconclusive.

Wileman, Stephens and Konvalina (1981, 1982) found that math ability significantly correlated with success on computer science final examinations. These results contradict Mazlack (1980) who found a non-significant relationship between mathematical aptitude and programming ability.

Brooks (1980) points out that many studies have failed to measure the time needed to understand the problem and program specifications. In addition, few (if any) studies have examined the effects of extreme time constraints and time allocation on testing, debugging and program modification in relation to code generation.

Locus of control (Rotter, 1966) is a personality trait that has been found to be an important factor in general academic perfomance. Internal individuals perceive their performance as a consequence of their own actions, whereas externals perceive their performance as being due to factors outside their own control. Findley and Cooper (1983), in an extensive review of the locus of control literature, concluded that

internality was positively correlated with academic achievement.

Frith (1967) found a curvilinear relationship between arousal and performance for both introverts and extraverts. Eysenck (1967) predicts that introverts require lower levels of arousal for the same level of performance done by extraverts. Thus, introverts would be expected of perform more poorly than extraverts under highly arousing situations (such as complex programming tasks) in which time is severely limited.

The Trait-State Anxiety Theory (King, Heinrich, Stephenson, & Speilberger, 1976) proposes the existence of both anxiety-prone individuals (trait anxiety, A-Trait) and situationally-produced anxiety. A high A-trait person is more likely to perceive a given situation (like taking tests) as threatening to self-esteem than a low A-trait individual. High A-traits have been associated with facilitated performance on simple tasks and degraded performance on complex tasks, such as computer programming, leading to the hypothesis that low A-trait individuals would be expected to perform better than high A-trait individuals on the present task.

Programming performance has hypothesized to significantly correlate with: 1) mathematical ability, 2) internality, since internality is associated with higher academic achievement; 3) extraversion, since extraverts tend to perform better than introverts in highly arousing situations; 4) low-anxiety trait characteristics, since low-anxiety-prone individuals tend to have higher performance on complex tasks than high-anxiety-prone individuals and 5) greater time allocation for computer interaction, since testing, debugging and modification require the bulk of programming time.

Methods

Subjects. In the present study, 14 male and 18 female participants were taking a college-level introductory computer science course, in

which 117 students were enrolled. The subjects had some previous exposure to computer programming languages (M = 0.91) and computer programming courses (M = 0.94, see Table 1). Most had a considerable mathematics background, both at the high school (M = 3.78 years) and college (M = 1.75 years) level.

Insert Table 1 about here

Materials. The programming task was performed on a Digital Equipment Corporation Rainbow 100 microcomputer and timed with a Cole Parmer Model 8668 digital stopwatch.

Subjects completed an adapted version of the Kovalina, Stephens, and Wileman (1983) math pretest comprising of 36-item multiple choice questions. This pretest, employed as a cognitive measure, is composed of 5 parts: descriptive information (11 questions), calculator simulator (5 questions), algorithm (5 questions) and word problems (5 questions). In addition to the math pretest, three different personality trait questionnaires, measuring introversion/extraversion, anxiety and locus of control, were given to subjects: 1) the Eysenck Personality Inventory (1964), composed of 57 yes/no questions, measuring introversion/extraversion; 2) the Taylor Manifest Anxiety State-Trait Scale (1953), consisting of 55 true/false questions, measuring the A-trait; 3) the Rotter Locus of Control (1966) Scale, consisting of 29 pairs of statements measuring internality/externality.

The intentions of the questionnaires were masked by either changed or omitted titles (e.g. Taylor Manifest Anxiety State-Trait Scale (1953) was called the "Personal Habits Questionnaire"). In addition, the subjects' confidentiality and anonymity were maintained by labeling all response materials with the student's identification number.

Procedure. The subjects' programming performance was measured by means of an evaluative grade from a 50-minute practical examination. Programs were evaluated by either tutors or teaching assistants, according to a standard format. Each program was evaluated separately by two raters on the basis of syntax (20 points), logical reasoning (30 points) and program specifications (50 points).

The subjects' time allocation for code generation and program implementation was also recorded, since subjects were allowed the opportunity to allocate their time spent writing and implementing their Pascal programs during the test within certain time constraints. The first 10 minutes was the minimum required time for the written part, in which the program would be generated on paper. Up to 40 minutes would be allowed for the completion of the written part. If the subjects had not completed the written part after 40 minutes, they were forced to begin implementing the program for the last 10 minutes of the 50 minute period. Thus, there was a 30-minute interval (between 10 and 40 minutes) during which the subjects could begin interacting with the microcomputer at any time.

Results

Pearson Product-Moment correlations were calculated giving the correlations between the performance on the practical examination and other factors felt to relate to programming (see Table 2).

Insert Table 2 about here

A stepwise multiple regression was performed on all factors included in the study (see Table 3). Time allocation was found to have the highest

correlation, accounting for 22 percent of the total variance ($R = 0.47$, $F(1, 30) = 8.43$, $p<.05$). The mean percentage of time spent on the code generation was 40.9 percent (20 minutes, sd = 7 minutes). As code generation time decreased, performance on the practical exam increased

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Insert Table 3 about here

A stepwise multiple regression was used to measure the cognitive and personality traits for their independent relatedness to performance on the practical examination without the other factors considered, since these were factors hypothesized to be associated with programming performance (see Table 4). Locus of control was also found to be a significant predictor of programming performance accounting for 14 percent of the total variance ($R = -0.38$, $F(1, 30) = 4.95$, $p<.05$). After this first level, the other 3 factors (math ability, introversion/extraversion, and anxiety) were non significant; $R = -0.02$, $F(1, 30) = 0.002$; $R = -0.21$, $F(1, 30) = 1.37$; and $R = -0.07$, $F(1, 30) = 0.15$, respectively; $p>.05$ in all cases). No further analyses were performed beyond this first step, since the partial correlations of the other variables would fall below the criterion level ($F(1, 20) < 3.90$).

Insert Table 4 about here

Discussion

As time allocated to code generation decreased and interactive program implementation increased, performance on the practical and interactive program implementation increased. The results support the

contention that greater time allocation for computer interaction is necessary, since testing, debugging and modifications require the bulk of programming time. This suggests that the importance of implementation time should be emphasized to students who are programming under restrictive time constraints.

Perhaps the most time intensive and frustrating part of programming is debugging, which requires a great deal of persistence and effort. This may explain the reason why internality is the strongest personality trait associated with high programming performance. Ducette and Wolk (1972) found that internals are more prone to persist at a given task and more willing to delay immediate rewards than externals. A high positive correlation found between internality and programming performance supports the notion that internals would be more likely to succeed at program implementation than externals.

The failure to find significant relationships between computer programming performance and anxiety may be due to the individualized effects of restrictive time intervals and self-paced format of the experimental design. Tobias (1979) suggested that time choice and time restrictions seem to have a differential effect on A-Trait persons. Mayer (1976) found that self-pacing within a certain time frame specified by the experimenter facilitated problem-solving performance for highly anxious subjects. Tobias' (1979) model of anxiety states that greater organization and choice of time allotment would result in better performance for high anxiety individuals and not for low anxiety persons. Thus, according to Tobias (1979) the restrictive time intervals and self-paced format would result in a nonsignificant correlation between A-Trait scores and practical exam performance.

A subject-selection bias towards high achievement students may account for the nonsignificant findings for both introversion/extraversion and anxiety dimensions. A post-hoc Chi Square analysis revealed a

significant difference between the subject programming performance and the overall computer class performance, $x^2(4, \underline{N} = 32) = 21.23$, $p<.05$. Overrepresentation of students who performed well on the practical examination confounded two basic assumptions made by the present experiment: 1) the programming task was complex and difficult and 2) the task was arousing and anxiety provoking. Since the programming task was of medium difficulty (rather than high difficulty) for the subjects, there would not be differential effects for introverts and extraverts as Eysenck (1967) would have predicted. In addition, a non-differential effect on performance for both high and low A-Trait individuals can be explained by a less arousing or anxiety provoking task.

Unexpectedly, math ability did not correlate with overall performance on the practical examination. The findings tend to support Mazlack's (1980) contention that no single academic discipline can be strongly associated with programming skill in itself. Computer science success (e.g. course grades) may not necessarily correspond to a reflection of true programming ability which is asssumed by both Mazlack (1980) and Konvalina, Stephens, and Wileman (1983). Perhaps the heavier weighting of written examinations (typical in most cases), which are further removed from programming, can account for the predictive success of math pretests. Although both written exams and practical examination require composition of programs, actual program implementation involves integrated implementation skills (e.g. testing, debugging and modification) which cannot be done on a written exam.

The present experiment's findings suggest the use of caution in utilizing mathematical pretests as predictors for computer science success. Moreover, testing for personality traits, such as internality, may prove to be useful additions to tests that advise students of their chances of computer science success.

Author Notes

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Table 1

Summary of
Cognitive and Personality Measures

	Mean	Standard Deviation
Current Grade Point Average	3.03	0.44
Computer Science Courses	0.94	0.84
Computer Program Languages	0.91	0.59
Years of High School Math	3.78	0.75
College Level Math Courses	1.75	1.05
Math Pretest (Correct Answer of 25)	17.56	4.91
Taylor Anxiety Test Score	16.66	8.43
Rotter I-E Score	11.41	3.64
Eysenck Personal Inventory	11.88	3.54

Note. N = 32

Table 2

Correlations with the Practical Examination

	Correlations	P-Value
Sex	-0.04	0.81
Age	-0.17	0.34
Current GPA	0.32	0.11
Hours of Study	0.09	0.63
Computer courses	0.36	0.04*
Non-Programming Experience	0.31	0.08
Programming Experience	0.04	0.84
Programming Languages	0.08	0.66
Typing Ability	0.12	0.52
Year of High School Math	-0.04	0.85
College Level Math Courses	0.33	0.06
Math Pretest	-0.06	0.73
Sequence & Logic	0.07	0.69
Calculator Simulator	0.00	1.00
Algorithm	-0.25	0.16
Word Problems	-0.05	0.77
State Trait Anxiety	-0.31	0.09
Time Allocation	-0.47	0.01*
Locus of Control	-0.38	0.02*
Introversion/Extraversion	-0.10	0.57
Current Test Grades	0.46	0.01*

Note. N = 32

Table 3

Significant Variables in Multiple Regression
Among All Possible Factors Considered
With Respect to Programming Performance

	STEP NO. 1 Time Allocation	STEP NO. 2 Current Test Grades	STEP NO.3 Non-programming Work Experience
MULTIPLE R	0.4684	0.6577	0.7102
MULTIPLE R^2	0.2194	0.4326	0.5044
ADJUSTED R^2	0.1934	0.3934	0.4513
STD. ERROR OF EST.	14.1289	12.2525	11.6538

Note. N = 32

Table 4

Variables in Multiple Regression:
Cognitive & Personality Factors Considered
With Respect to Programming Performance

	R	F(1,30)
Locus of Control	-0.38	4.950*
Math Ability	-0.02	0.002
Introversion/Extraversion	-0.21	1.370
Anxiety	-0.07	0.150

	Step 1
	Locus of Control
Multiple R	-0.38
Multiple R^2	0.14
Adjusted R^2	0.12
Std. Error of Est.	3.54

Note. N = 32

* denotes $p<0.5$